Joint Polar Satellite System (JPSS) Cross-Track Infrared Microwave Sounding Suite (CrIMSS) Environmental Data Record Validation Status

Nicholas R. Nalli,[1,2] Christopher D. Barnet,[1]

Murty Divakarla,[1,2] Lihang Zhou,[1,3] Degui Gu,[4] Xu Liu,[5] Susan Kizer,[5] Xiaozhen Xiong,[1,2] Guang Guo[1,6], T. Reale,[1] B. Blackwell,[7] *et al.*

[1] NOAA/NESDIS/STAR, Camp Springs, Maryland, USA
[2] I.M. Systems Group, Inc., Rockville, Maryland, USA
[3] JPSS Office, Lanham, Maryland, USA
[4] Northrop Grumman Aerospace Systems (NGAS), Redondo Beach, CA, USA
[5]NASA Langley Research Center, Hampton, VA, USA
[6]Riverside Technology, Inc., Silver Spring, MD, USA
[7]MIT Lincoln Laboratory, Lexington, MA, USA

Et al. …

- Bomin Sun, Frank Tilley and Michael Pettey (NOAA/NESDIS/STAR NPROVS developers)
- A. Gambacorta, E. Maddy, M. D. Goldberg (NOAA/NESDIS/STAR)
- D. Tobin, R. Knuteson, H. Revercomb (UW/CIMSS)
- L. Strow (UMBC)
- J. Susskind (NASA/GSFC)
- E. Joseph and V. Morris (Howard Univ./NCAS)

Outline

- **CrIMSS (CrIS/ATMS) EDR Product Overview**
  - AVTP, AVMP (KPPs), AVPP, O_3 (IP)
  - JPSS Specification Performance Requirements
- **Cal/Val Program Status Highlights**
  - Overview
    - Team Members (roles and responsibilities)
    - Phases
  - Pre-Launch Phase Efforts
  - EOC–ICV Phase Near-Term Efforts

Launch of NPP!

Vandenberg Air Force Base (VAFB)

Space Launch Complex 2 (SLC-2)

28 Oct 2011

From NASA streaming video of launch

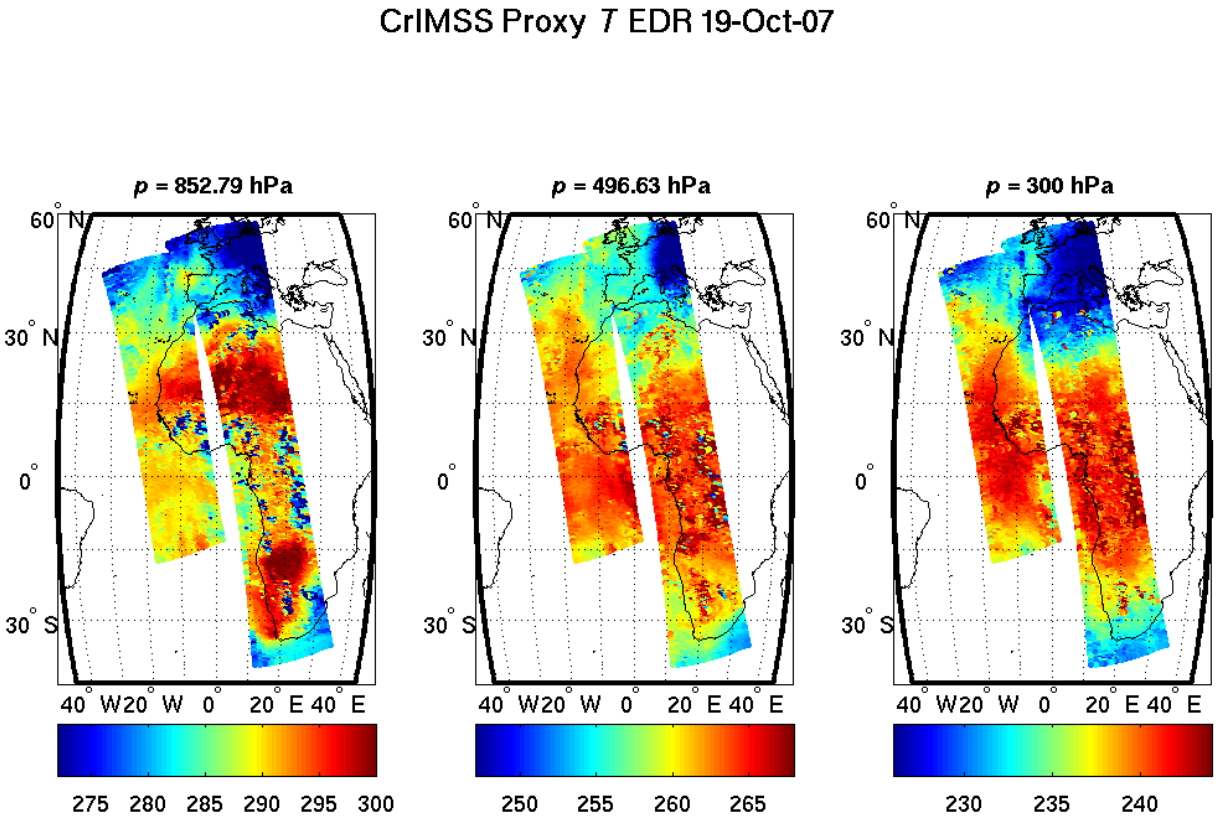
From NASA streaming video of launch

CrIMSS EDR

PRODUCT OVERVIEW

Atmospheric Vertical Temperature Profile (AVTP)

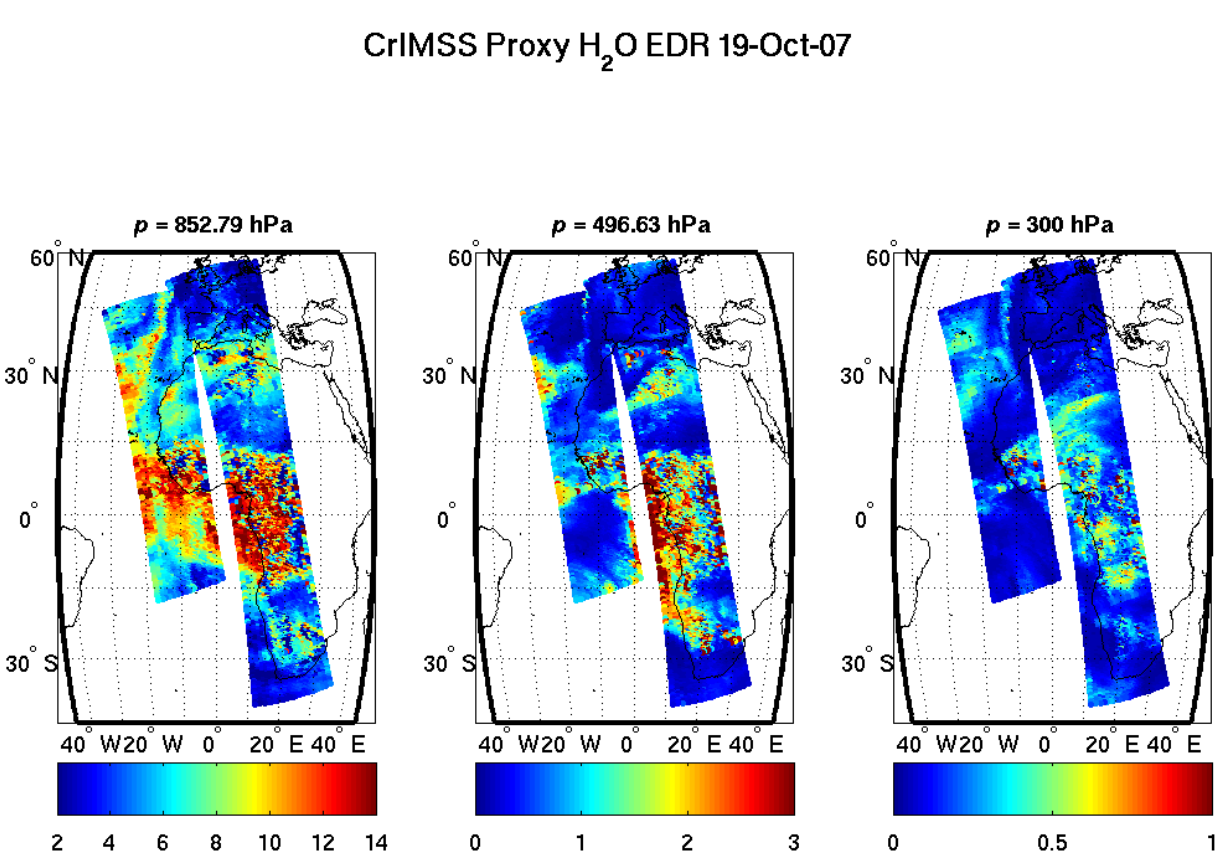
- **EDR** used for initialization of NWP models, forecasting / nowcasting weather, severe weather, cloud cover and winds, basic science research, etc.
- **Non-precipitating scenes**
- **Key Performance Parameter (KPP)** for lower tropospheric temperature



CrIMSS AVTP EDR retrieved from SDR Proxy Data

Atmospheric Vertical Moisture Profile (AVMP)

- **EDR** used for initialization of NWP models, forecasting / nowcasting weather and severe weather, vertical and horizontal cloud info, basic science research, etc.
- **Non-precipitating scenes**
- **Key Performance Parameter (KPP)** for lower tropospheric water vapor



CrIMSS AVMP EDR retrieved from SDR Proxy Data

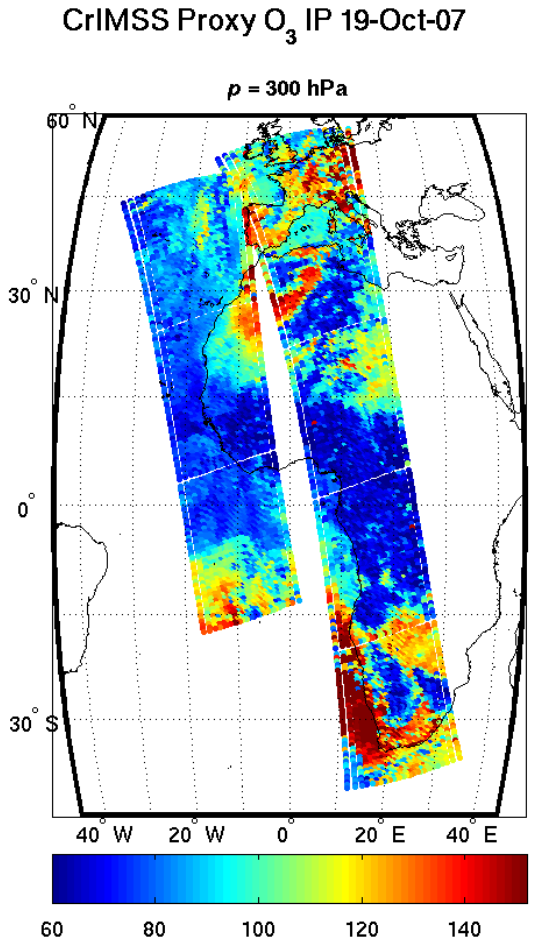
JPSS Specification Performance Requirements

Atmospheric Vertical Temperature Profile (AVTP) Measurement Uncertainty – Layer Average Temperature Error		
PARAMETER	**THRESHOLD**	**OBJECTIVE**
AVTP Clear, surface to 300 mb	**1.6 K / 1-km layer**	**0.5 K / 1-km layer**
AVTP Clear, 300 to 30 mb	1.5 K / 3-km layer	0.5 K / 3-km layer
AVTP Clear, 30 mb to 1 mb	1.5 K / 5-km layer	0.5 K / 5-km layer
AVTP Clear, 1 mb to 0.5 mb	3.5 K / 5-km layer	0.5 K / 5-km layer
AVTP Cloudy , surface to 700 mb	**2.5 K / 1-km layer**	**0.5 K / 1-km layer**
AVTP Cloudy, 700 mb to 300 mb	1.5 K / 1-km layer	0.5 K / 1-km layer
AVTP Cloudy, 300 mb to 30 mb	1.5 K / 3-km layer	0.5 K / 3-km layer
AVTP Cloudy, 30 mb to 1 mb	1.5 K / 5-km layer	0.5 K / 5-km layer
AVTP Cloudy, 1 mb to 0.5 mb	3.5 K/ 5-km layer	0.5 K / 5-km layer

Atmospheric Vertical Moisture Profile (AVMP) Measurement Uncertainty – 2-km Layer Average Mixing Ratio % Error		
PARAMETER	**THRESHOLD**	**OBJECTIVE**
AVMP Clear, surface to 600 mb	**Greater of 20% or 0.2 g/kg / 2-km layer**	**10% / 2-km layer**
AVMP Clear, 600 to 300 mb	Greater of 35% or 0.1 g/kg / 2-km layer	10% / 2-km layer
AVMP Clear, 300 to 100 mb	Greater of 35% or 0.1 g/kg / 2-km layer	10% / 2-km layer
AVMP Cloudy, surface to 600 mb	**Greater of 20% of 0.2 g/kg / 2-km layer**	**10% / 2-km layer**
AVMP Cloudy, 600 mb to 400 mb	Greater of 40% or 0.1 g/kg / 2-km layer	10% / 2-km layer
AVMP Cloudy, 400 mb to 100 mb	Greater of 40% or 0.1 g/kg / 2-km layer	NA

Atmospheric Vertical Pressure Profile (AVPP); Trace Gas IP and P^{3}I

- **AVPP is an EDR** derived from AVTP and AVMP.
- Trace gas retrievals from IR sounders are desirable for basic science
  - O_3 is an intermediate product (IP) necessary for optimal EDR retrieval
  - CO and CH_4 are experimental (P^{3}I) products (not funded within cal/val program)



CrIMSS O_3 IP retrieved from SDR Proxy Data

CrIMSS EDR

CAL/VAL PROGRAM STATUS HIGHLIGHTS

CrIMSS Cal/Val Overview

- **NPP CrIMSS EDR Cal/Val Plan:** ensure the data products comply with the requirements of the sponsoring agencies and have met their **global performance specifications**

- **Draw on lessons learned** from validating the **AIRS/AMSU** and **IASI/AMSU/MHS sounding systems**.
  - **Use proven datasets** for global validation (ECMWF, NCEP/GFS, RAOBs, etc)
  - **Subject Matter Experts (SME) Team** from both user and science communities for heritage knowledge, experience and tools, and assure understanding of customer mission success
  - **Leverage existing capabilities** wherever possible
    - Operational real-time systems (ATOVS, GOES), NPROVS
    - AIRS and IASI processing and validation systems and routine instrument monitoring and characterization
    - Intensive field campaign (aircraft sensor) cal/val experience
  - **Assessments against current capabilities** using **heritage sensors and algorithms**
    - Hyperspectral AIRS and IASI systems (well established comparable products)
    - ATOVS (HIRS/AMSU) operational products to demonstrate the value of hyperspectral measurements (NPROVS)

- **Roll-up of regional assessments** approach for assessing that EDRs have met **global spec**
  - Typical validation methods characterize the performance of the EDRs in various ensembles of cases
  - Specifically, this involves stratifying specs according to various bins:
    - day/night and latitude bands (i.e., polar, midlatitude, tropical)
    - land/ocean/ regional, and (possibly) altitude and surface characteristics

Team Members – Roles & Responsibilities

Cal/Val	Name	Organization	Funding Agency	Task
NOAA Team Members				
Lead	Chris Barnet	NOAA/NESDIS/STAR	NJO	Lead CrIMSS EDR Team
AVTP/AVMP	Changyong Cao	NOAA/NESDIS/STAR	NJO	Coordination w/ GSICS
AVTP/AVMP	Mitch Goldberg	NOAA/NESDIS/STAR	NJO & NOAA-PSDI	NGAS-code, NUCAPS
AVTP/AVMP	Anthony Reale	NOAA/NESDIS/STAR	NJO	NPROVS
AVTP/AVMP	Fuzhong Weng	NOAA/NESDIS/STAR	NOAA-PSDI	MiRS
CrIS SDR	Yong Han	NOAA/NESDIS/STAR	NJO	Lead CrIS SDR
ATMS SDR	Tsan Mo	NOAA/NESDIS/STAR	NJO	Lead ATMS SDR
NOAA-External Team Members				
AVTP/AVMP	Bill Blackwell	MIT	NJO	Microwave products
AVTP/AVMP	Allan Larar	NASA/LaRC	NJO	EDR Validation
AVTP/AVMP	Xu Liu	NASA/LaRC	NJO	IASI proxy, EDR validation
AVTP/AVMP	Hank Revercomb	SSEC	NJO	SDR, PEATE
AVTP/AVMP	Dave Tobin	SSEC	NJO	ARM-RAOBS
AVTP/AVMP	Larrabee Strow	UMBC	NJO	OSS validation
AVTP/AVMP	Joel Susskind	NASA/GSFC	NJO	AIRS proxy
CrIMSS SDR	Steven Beck	Aerospace Corp.	external	RAOB, LIDAR
CrIMSS SDR	Steven English	UKMET	external	UKMET analysis
CrIMSS SDR	William Bell	ECMWF	external	ECMWF analysis
AVTP/AVMP	Steve Friedman	NASA/JPL	NASA	Sounder PEATE
AVTP/AVMP CrIS SDR	Denise Hagan Degui Gu	NGAS	NG Prime	EDR Validation / SDR coordination

Cal/Val Phase Overview

- *Pre-Launch*
- *Early Orbit Checkout (EOC)*
  - *L* + 90 days, as sensors are activated
- *Intensive Cal/Val (ICV)*
  - Stable SDR out to *L* + 24 months
  - Validation of EDRs against multiple correlative datasets
- *Long-Term Monitoring (LTM)*
  - From end of ICV (*L* + 24 months) to the end of operational lifetime
  - Characterization of all EDR products and long-term demonstration of performance

EDR Validation Activities by Phase (1/2)

Pre-Launch – Early Orbit Checkout

- **Pre-launch**
  - **Global synthetic datasets**
    - Tests algorithm for theoretical robustness – self-consistent temperature, moisture, ozone, and cloud water profiles are "controlled"
    - Simulated for a wide range of environmental scenes, including seasonal, diurnal, spatial variability, and sensor scanning geometry
  - **Proxy datasets**
    - Data derived from existing satellite systems with similar specs (here AIRS/AMSU and IASI/AMSU)
    - Used to test concepts and exercise CrIMSS algorithm ; support launch readiness (functionality of the code, develop methods of empirical bias correction) and porting of algorithms
    - Aqua/AIRS (9 IR FOVs and 01:30 orbit); METOP/IASI (exact IR radiance spectral transform and MHS channels)

- **Early Orbit Checkout**
  - **Model comparisons**
    - Useful at first light and for long-term monitoring
    - Similar to AIRS science team activities using ECMWF and NCEP/GFS
    - Compare forward models, sanity checks on "obs – calc"
  - **Simultaneous nadir overpass and double differencing** of radiances
  - **Inter-compare** with operational AIRS and/or IASI products
    - Initially (first light) use off-line versions of CrIMSS products.
      - Even if retrievals are poor, having geophysical state and diagnostics can help identify problems.
    - Useful to identify and mitigate issues with the NGAS EDRs
  - **PCA analysis** of noise characteristics and instrument monitoring
    - Can be used to verify instrument noise, random and systematic components, and monitor instrument health

EDR Validation Activities by Phase (2/2)
Intensive Cal/Val – Long-Term Monitoring

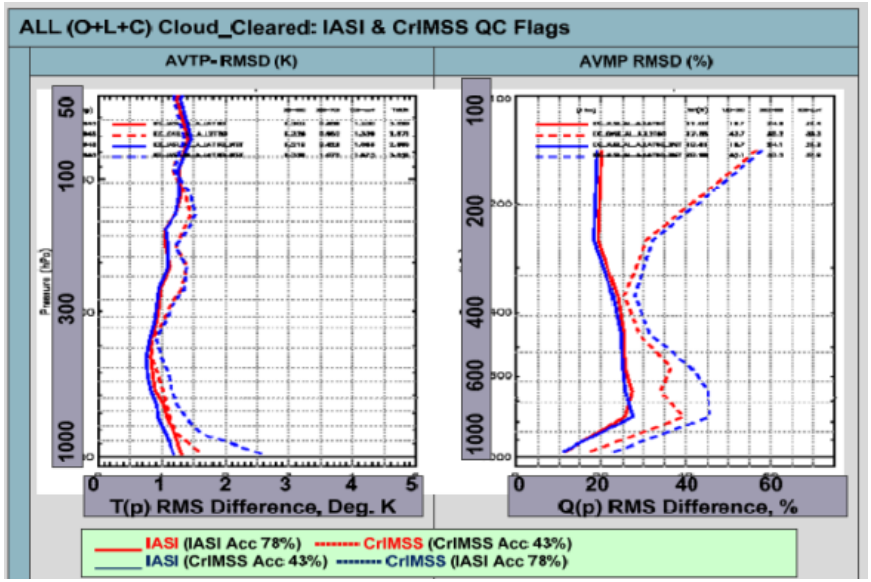
- **Operational RAOBs**
  - Useful for **long-term characterization** and **global latitude representation**. After couple months should begin to have significant statistics.
  - Tony Reale's NOAA Products Validation System (NPROVS)

- **Dedicated RAOBs**
  - Useful for **regional characterization**.
  - Will take many months (years?) to accumulate enough statistics.
  - Need site support and funding for large number of RAOBs.
  - Ideally coordination through GCOS Reference Upper Air Network (GRUAN)

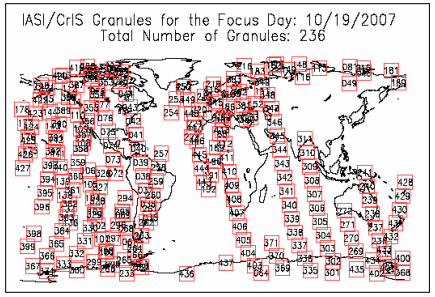
- **Intensive Field Campaigns** (e.g., *Tobin et al.* 2006, *Nalli et al.* 2006, *JGR,* **111**; *Taylor et al.* 2008, *BAMS,* **89**; *Blackwell et al.* 2001, *TGARS,* **39**)
  - Useful for **regional characterization** and **SDR cal/val**; state specification for "cal/val dissection"
  - Scientific campaigns of opportunity
    - Low cost, low risk; synergism; engages science community
    - **NOAA Aerosols and Ocean Science Expeditions (AEROSE)** (*Nalli et al.* 2011, *BAMS*, **92**(6)), linkage to GOES-R program

Pre-Launch Phase Efforts (1/3)

- **Proxy Data Results**
  - **CrIS/ATMS proxy SDRs generated**
    - IASI/AMSU based
      - Focus Day 19-Oct-07
      - 12 days global RAOBs
      - NOAA AEROSE 2010-11 campaigns
      - Include matched ECMWF/NCEP-GFS, IASI/AMSU-A/MHS, and proxy CrIS/ATMS SDRs
      - Available on NOAA/STAR FTP ftp://ftp2.orbit.nesdis.noaa.gov/smcd/tking/CrIMSS_CALVAL/
    - AIRS/AMSU based
      - Raytheon Plantinum-72 (P72) data package
      - IDPS operational CrIMSS SDR/EDR
      - Available on GRAVITE FTP during JPSS Rehearsal
  - **CrIMSS EDR runs**
    - NGAS ADA environment
    - IDPS operational algorithm and environment
    - LaRC v1.5 operational algorithm, STAR offline environment
    - STAR NUCAPS algorithm
    - CrIMSS EDR products retrieved from proxy data compared reasonably against ECMWF/RAOB matchups, and current products
    - *Divakarla et al.* (AMS, HISE, 2011); *Gu et al.* (AMS, 2011)
    - **Cf. Oral 3.8 (*Divakarla et al.*)** this session
  - **CrIS Radiance Bias Tuning**
    - The radiance bias-tuning procedures which are currently used in IASI NOAA-unique Level 2 products are being used for CrIS radiance bias tuning.
    - Focus day (19 Oct 2007) ECMWF (original and "improved" for RTM) data were used to calculate radiance using the OSS model and Hamming apodization. Only the final subsets of clear, night, and ocean cases within 65° will be used in the tuning shown in the spectral OBS − CALC plots.



Focus Day Proxy Data



Prelaunch CrIS Tuning

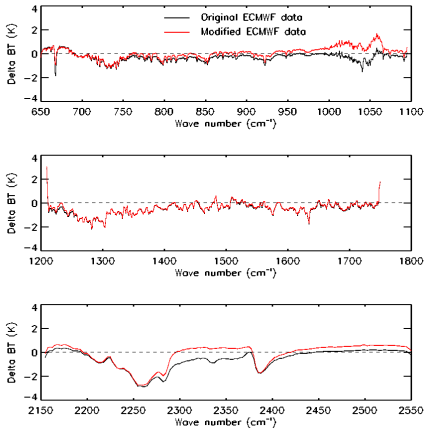
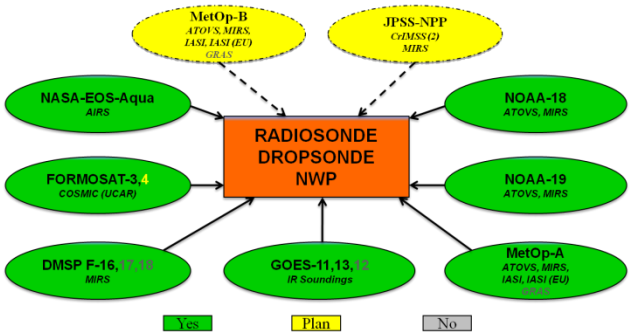


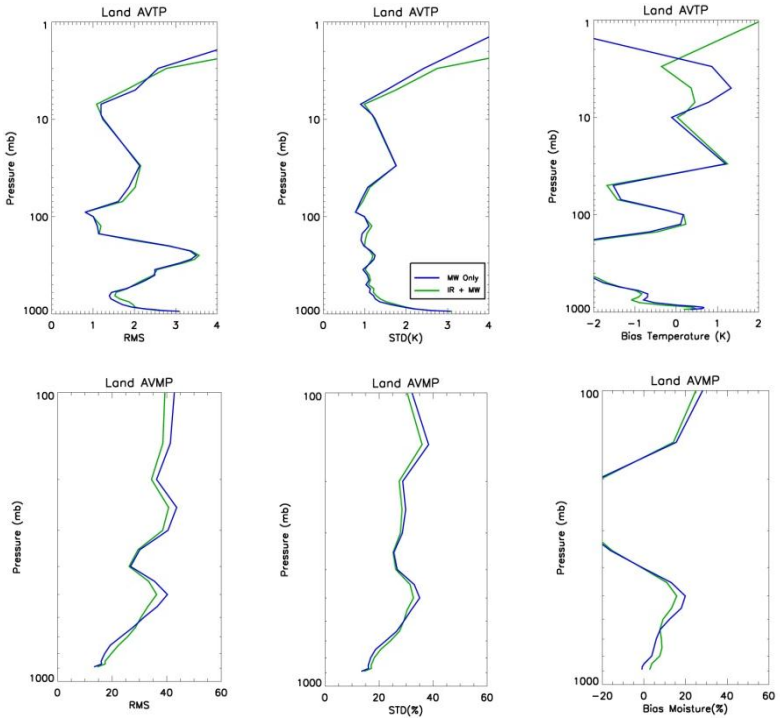
Figure courtesy of G. Guo

Pre-Launch Phase Efforts (2/3)

- **NOAA Products Validation System (NPROVS)**
  - Profile Display (PDISP) and NPROVS Archive Summary (NARCS) analytical interface clients (JAVA)
  - Inter-comparisons of different satellite systems, in addition to RAOB
  - http://www.star.nesdis.noaa.gov/smcd/opdb/poes/NPROVS.php
  - For more information, cf.
    - Oral 8.3 (*Reale et al.*) and 13.1 (*Pettey et al.*)
    - Poster 509 (*Sun et al.*) and 169 (*Reale et al.*)

- **JPSS Cal/Val Rehearsal-2**
  - Successfully held 22-26 August 2011
  - Detailed work plan on using data downloaded from GRAVITE and CLASS, including utility of Focus Day and other datasets generated at STAR
  - SDR and EDR proxy data sets were quality checked and concerns on the data quality, aggregation issues, and download limitations from the CLASS were reported to the JPSS Management





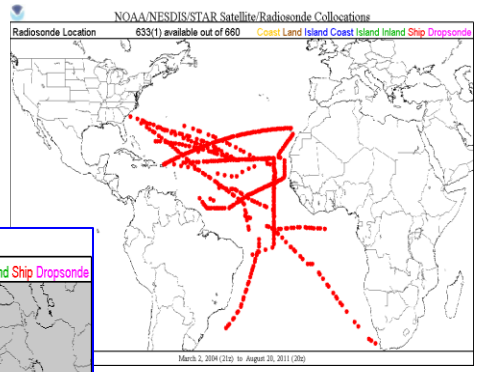
Pre-Launch Phase Efforts (3/3)

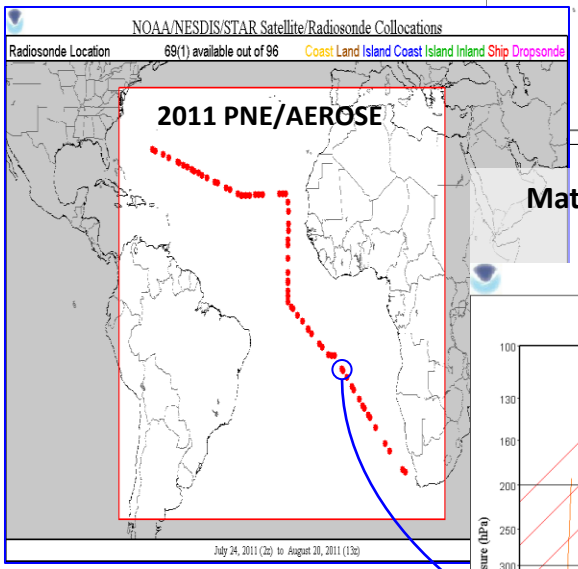
- **NOAA PNE/AEROSE Campaigns**
  - Ship-based validation campaigns
  - Dedicated RAOB (*PTU*, *z*, wind, O_3) over the tropical North Atlantic Ocean
  - Ocean region **germane to the CrIMSS mission**
    - Saharan air layer (SAL) and tropical water vapor
    - Dust and biomass burning aerosols
    - Tropospheric ozone dynamics
  - AEROSE 2011 campaign successfully conducted in August

- **AEROSE 2010, 2011 proxy datasets** were developed by NOAA/STAR, MIT, and LaRC
  - Available on STAR FTP server
  - Dust impact risk reduction
  - **Cf. Oral 3.8 (*Divakarla et al.*)** this session
  - **Cf. Poster Session 2 500 (*Nalli et al.*)**

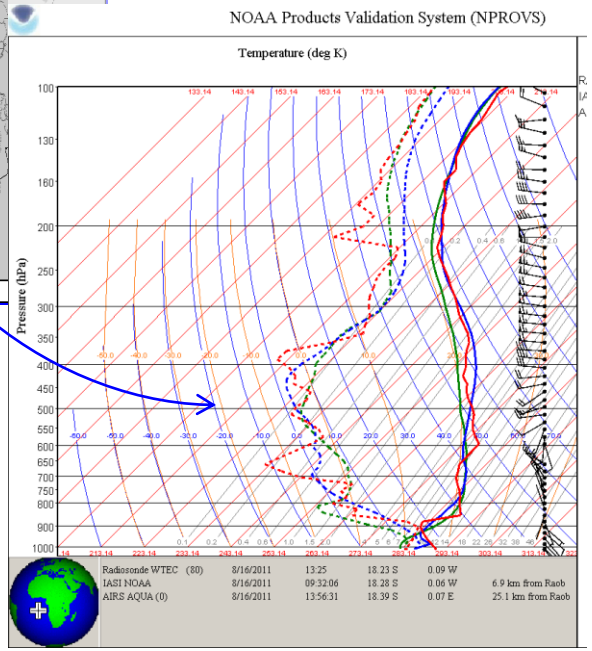
- **Next AEROSE – September 2012**
  - Assuming no changes to schedule, this will be first campaign of opportunity to provide **dedicated RAOB matchups** over open ocean for **ICV phase NPP CrIMSS cal/val**
  - September is during the **peak of the Atlantic hurricane season**

AEROSE RAOB matchups (IASI and AIRS) available for analysis in NPROVS





Matchup selected within Biomass Burning Smoke Plume



EOC–ICV Phase Near-Term Efforts

- Early assessments will be obtained using matched ECMWF fields
- During this time, global operational RAOB-NPP matchups will be accumulated for a statistical in situ sample
- Efforts to coordinate a funding mechanism for dedicated RAOBs from ARM sites is currently ongoing
- Assuming no changes in scheduling, the 2012 NOAA AEROSE campaign will provide dedicated RAOB-NPP matchups over open ocean

Early Orbit Checkout Milestones	
Date	**Milestone**
28 Oct 2011	NPP Launch
08 Nov 2011	ATMS First Light
17 Nov 2011	NPP reaches mission orbit
21 Nov 2011	VIIRS First Light
Dec 2011 – Jan 2012	ATMS Tuning
Mar 2012	CrIS First Light
May 2012	CrIS Tuning
May 2012	Segue into ICV phase of Cal/Val Plan
30 Jun 2012	Beta Stage Validation Report

CrIMSS EDR Maturity					
Algorithm	**Beta**	**Provisional**	**Val 1**	**Val 2**	**Val 3**
EDRs AVTP, AVMP, and AVPP	L + 6m	L + 12m	L + 18m	L + 24m	L + 36m

Summary

- The status of the **NPP CrIMSS EDR Cal/Val Program** for Sounding EDRs was overviewed in this presentation. The validation program is to ensure the data products comply with the requirements of the sponsoring agencies (i.e., meet spec).

- **Pre-launch Cal/Val efforts have been successful for demonstrating launch readiness** in exercising and performing initial tests of the IDPS EDR algorithm through the development of "proxy datasets," including focus days and intensive campaigns-of-opportunity.

- **Early-Orbit Checkout Cal/Val efforts** are currently underway in preparation for the Intensive Cal/Val (ICV) phase to follow.